

The Role of Dams in Sustainable Development

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Abstract

Dams are a relatively inexpensive source of power. However, the arguably ecological destruction caused by dams make them an unsustainable source of energy. Herein, we argue that since the ecological cost from dam construction is high, alternative renewable energy sources would better attain a sustainable development strategy.

Keywords

Energy; Ecology; Sustainable Development; Non-sustainable Energy; Renewable Energy

Introduction

After centuries of unrestrained addiction by government officials to the pursuit of economic development through the construction of huge or super hydro-electric dams, indications are that humankind is waking up to the reality that the economic, political, social, cultural, ecological, moral and environmental costs of this technological choice seem to be consistently outstripping its benefits. To many people, big dams have instead become a nightmare. Nevertheless, more and more superior huge dams continue to be pushed by governments and financiers as the wise choice to development particularly in the poor regions of the world (1). And, as we will argue, alternative viable sustainable development and technological alternatives exist.

Ecology, Development, and Energy

Fundamentally, a healthy physical environment is essential to sustainability. However, environmental integrity often suffers with economic development and population growth. For example, according to a study "Livestock's Long Shadow" by the Food and Agriculture Organization of the United Nations, as the world's population increase along with the demand for meat, there will be less land and water for the

population to survive. Also, the production of meat is inefficient because it requires more food than it yields. Furthermore, 18% of global warming is caused by the methane produced by these animals and the nitrogen rich manure (2;3).

As a possible solution, we might seek other sources of protein. For example, From an ecological perspective, insects have a lot to recommend them. They are renowned for their small "foodprint"; being cold-blooded, they are about four times as efficient at converting feed to meat as are cattle, which waste energy keeping themselves warm. Ounce for ounce, many have the same amount of protein as beef – fried grasshoppers have three times as much – and are rich in micronutrients like iron and zinc (4).

Further, an experiment was conducted to quantify production of carbon dioxide (CO₂) and average daily gain (ADG) as a measure of feed conversion efficiency, and to quantify the production of the greenhouse gases methane (CH₄) and nitrous oxide (N₂O) as well as NH₃ by five insect species of which the first three are considered edible: *Tenebrio molitor*, *Acheta domesticus*, *Locusta migratoria*, *Pachnoda marginata*, and *Blattella germanica*. Large differences were found among the species regarding their production of CO₂ and GHGs. The insects in this study had a higher relative growth rate and emitted comparable or lower amounts of GHG than described in literature for pigs and much lower amounts of GHG than cattle. The same was true for CO₂ production per kg of metabolic weight and per kg of mass gain. Furthermore, also the production of NH₃ by insects was lower than for conventional livestock. This study therefore indicates that insects could serve as a more environmentally friendly alternative for the production of animal protein with respect to GHG and NH₃ emissions. The results of this study can be used as basic information to compare the production of insects with conventional livestock by means of a life cycle analysis (5).

Although China is the world's largest producer of wheat and rice, and the second-largest producer of corn, behind the U.S., the country is not producing enough. That forces China to import more crops—a rare category in which the U.S. is a net exporter to China—to keep volatile food prices from stirring up discontent. China's ability to grow more grain is limited. There isn't much arable land that isn't already under plow and the water table in some areas is falling amid heavy irrigation. The surest way for China greatly to increase its harvests is to raise field productivity—an area ripe for improvement. Chinese corn farmers produce an average of 85 bushels an acre compared with about 158 bushels for U.S. farmers, according to the U.S. Agriculture Department (6).

A big difference between U.S. farmers and their Chinese counterparts is crop biotechnology. Outside of cotton and papaya, few of Chinese crops are genetically modified. In the U.S., where genetically modified seeds were introduced commercially in the mid-1990s, the vast majority of the corn, soybeans and cotton are bioengineered. The Chinese government is doing extensive crop-biotechnology research, but the country remains far behind the U.S. in terms of commercialization partly because Beijing, leery of ceding control of its food supply to outsiders, has wanted to control the technology.

The Chinese government is concerned about food security because the expanding economy is creating more middle-class families who want to upgrade their diets by eating more meat and drinking more milk, which requires crops for feeding livestock. China imports nearly a quarter of the U.S. soybean crop, in part to fatten hogs and chickens craved by China's middle class. Also, corn prices have moved higher at the Chicago Board of Trade because traders believed China is on the verge of importing millions of metric tons of U.S. corn (7).

As is widely known, fossil fuels (coal, oil, and gas) emit carbon dioxide into the environment. Both China and the United States rely on fossil fuels for the majority of their energy needs. These fuels are cheaper than alternative and renewable fuels though decreasing.

Recently, the decreasing cost of solar panels has caused two manufacturers from the U.S. to file for bankruptcy. In particular, Evergreen Solar, Inc., once a darling of the U.S. solar industry, filed for bankruptcy, saying that it couldn't compete with Chinese competitors without a reorganization. When Evergreen developed a technology that uses less polysilicon - material housing

small silicon crystals – in 2008, this raw material cost \$400 per kilogram. The cost now is \$55 to \$65 per kilogram. Chinese solar manufacturers enjoy extensive support from industrial policy, such as inexpensive capital, low-cost electricity, and real estate. Also, workers in China are paid \$1 an hour versus \$15 an hour in Evergreen's Massachusetts's plant (8).

Solyndra's costs stayed high because of the tricky manufacturing process. In late 2009, Solyndra's tubes cost \$4 for every watt of power output to produce. The problem was the company could sell them for only \$3.24 per watt. Also, losses resulted from having to discard defective panels and costly materials from faulty manufacturing processes. Solyndra uses a cylindrical model rather than a photovoltaic panel. Furthermore, after receiving \$535 million loan guarantee from the federal government, they over-expanded (9).

Hydroelectric Power: A Renewable Energy Source

Moving water is a powerful entity responsible for lighting entire cities, even countries. Thousands of years ago the Greeks used water wheels, which picked up water in buckets around a wheel. The water's weight caused the wheel to turn, converting kinetic energy into mechanical energy for grinding grain and pumping water. In the 1800s the water wheel was often used to power machines such as timber-cutting saws in European and American factories. More importantly, people realized that the force of water falling from a height would turn a turbine connected to a generator to produce electricity. Niagara Falls, a natural waterfall, powered the first hydroelectric plant in 1879.

Man-made waterfalls dams were constructed throughout the 1900s in order to maximize this source of energy. Aside from a plant for electricity production, a hydropower facility consists of a water reservoir enclosed by a dam whose gates can open or close depending on how much water is needed to produce a particular amount of electricity. Once electricity is produced it is transported along huge transmission lines to an electric utility company.

By the 1940s, the best sites for large dams had been developed. But like most other renewable sources of energy, hydropower could not compete with inexpensive fossil fuels at the time. It wasn't until the price of oil skyrocketed in the 1970s that people became interested in hydropower again. Today one-fifth of global electricity is generated by falling water.

Over the past 100 years, the United States has led the world in dam building. Secretary of the Interior Bruce Babbitt recently observed that, "on average, we have constructed one dam every day since the signing of the Declaration of Independence. Of the 75,187 dams in the US, less than 3% are used to produce 10-12% of the nation's electricity. With over 2,000 facilities, the US is the second largest producer of hydropower worldwide, behind Canada. The dams that do not produce electricity are used for irrigation or flood control. Many people believe these pre-existing sites could contribute to the country's power supply in a cost-effective manner if hydroelectric facilities were constructed.

Hydropower has become the leading source of renewable energy. It provides more than 97% of all electricity generated by renewable sources worldwide. Other sources including solar, geothermal, wind, and biomass account for less than 3% of renewable electricity production. In the US, 81% of the electricity produced by renewable sources comes from hydropower. Some regions depend on it more than others. For example, 75% of the electricity produced in New Zealand and over 99% of the electricity produced in Norway come from hydropower.

The use of hydropower prevents the burning of 22 billion gallons of oil or 120 million tons of coal each year. In other words, the carbon emissions avoided by the nation's hydroelectric industry are the equivalent of an additional 67 million passenger cars on the road 50 percent more than there are currently. The advantages of hydropower are therefore convincing, but there are some serious drawbacks that are causing people to reconsider its overall benefit. (please go to website: altenergy.org/renewables/hydroelectric.html).

The Ecology of Dams

Rivers possess a delicate ecology that depends on a regular cycle of disturbance within certain tolerances. The plant and animal communities that inhabit the river and river margins have evolved to adapt to their river's own peculiar pattern of flood and drought, slow and fast current. Dams disrupt this ecology.

There are several types of dams. Check dams prevent flooding of small areas. Diversion dams divert river water to irrigate crops. Large dams may be built for flood control or electrical generation, or both. Flood control dams are often earth dams--made of huge mounds of clay, sand, gravel, and rock--but often made of concrete. Hydroelectric dams are concrete marvels of engineering. This section will examine mostly the large

dams: flood control and hydroelectric dams.

Interrupting Natural Cycles

The first effect of a dam is to alter the pattern of disturbances that the plants and animals of a river have evolved for. Many aquatic animals coordinate their reproductive cycles with annual flood seasons. Every flood is valuable in that it takes nutrients from the land and deposits them in the river, providing food for the stream's residents. Floods also provide shallow backwater areas on vegetated and shaded riversides; the young of many animals depend on these backwaters to protect them from large predators.

As an example, a fish on a certain river may only reproduce during April of every year so that its offspring will have abundant food and places to hide. If the flood never comes because a dam holds the river back, the offspring may be produced during a time when they cannot possibly survive. If the fish can wait until the next flood, which may be in July or may be in October, its young will be born during the wrong time of year, and will have to contend with the absence of their normal food supply and temperatures for which they are not prepared (10).

Vegetation, too, depends upon these regular cycles of flood. Quite often, people will decide that they can spare no water at all and no flooding will occur. Or they may have built the dams specifically to stop flooding, so they can build houses in the floodplains. When this happens, riparian vegetation, the vegetation bordering the river, changes forever. An example of this may be found in much of the Southwest United States, where enormous floodplains of cottonwood and marsh have been replaced by dry, barren areas of tamarisk and grass (11).

Dams hold back not only sediment, but also debris. The life of organisms (including fish) downstream depends on the constant feeding of the river with debris. This debris includes leaves, twigs, branches, and whole trees, as well as the organic remains of dead animals. Debris not only provides food, it provides hiding places for all sizes of animals and surfaces for phytoplankton and microorganisms to grow. Without flooding and without a healthy riparian zone, this debris will be scarce. Adding to the problem, although debris might come from the river above the dam, it is instead trapped in the reservoir, and never appears downstream. The bottom level of the food web is removed. All in all, the loss of sediment and debris means the loss of both nutrients and habitat for most animals (please see:

chamisa.freeshell.org/dam.htm).

Dams in China

Recently, the Chinese State Council has removed a crucial roadblock to building the Xiaonanhai Dam on the Yangtze River. In a little-noticed ruling made public on Dec. 14, 2011, the council approved changes to shrink the boundaries of a Yangtze River preserve that is home to many of the river's rare and endangered fish species. The decision is likely to clear the way for construction of the Xiaonanhai Dam, a \$3.8 billion project that environmental experts say will flood much of the preserve and probably wipe out many species. Chinese environmental groups and the Nature Conservancy have waged a long battle against the Xiaonanhai Dam, one of 19 dams proposed or under construction on the upper reaches of the Yangtze. The dams will turn the river from a swift-running stream that drops from its source in Qinghai Province, three miles high, into a series of large, slow-moving lakes.

The projects are part of a frenetic and much-criticized rush into hydroelectric power by the Chinese government, which, with 26,000 such dams, already has more than any nation in the world. At 1,760 megawatts, the Xiaonanhai project is comparatively small by Yangtze standards, but still three-quarters the size of the Hoover Dam, *Scientific American* reported in 2009. Critics say the project makes little economic sense except as a temporary job creator. The reservoir will flood 18 square miles of prime farmland and displace 400,000 people, driving the cost of every kilowatt of generating capacity to \$2,144 — triple that of the Three Gorges dam, according to Fan Xiao a geologist who has fought the project for years. The national reserve that critics say will be destroyed by the dam was, in fact, established to address concerns that the Three Gorges dam would endanger the fish population. Of the Yangtze's 338 freshwater fish species, 189 live in the reserve — and many of those are found in no other river basin in China (12).

Arguably, the Three Gorges Dam has also had some deleterious effects on the environment. As discussed previously (13), a nearly blind white dolphin in China, the baiji, which survived 20 million years has been declared possibly extinct according to Robert Pitman and August Pfluger (14) who completed a six week search for any surviving baiji. The expedition began on the Yangtze River from the Three Gorges dam and ended in Shanghai. However, recently, a videotape from the Yangtze River in central Anhui Province

providing slim hope for the baiji's survival (15). The last sighting of this huge sturgeon was in 2003. It has been concluded that sonar that blocks the dolphins ability to find food, pollution, and over-fishing has "functionally" caused the baiji's extinction (or near). Also, importantly, the Three Gorges dam has stopped the dolphin from returning to its breeding ground in the upper Yangtze deep into the Tibetan plateau (16). Further, in the upper Yangtze River, forest coverage has dropped from 30-40% in 1950 to 10% in 1998. Also, in 2002, 48.5% (approx.) of the southern Yangtze River was unsuitable for human contact (17). A report in *China Daily* cited that 370 miles and 30 percent of the Yangtze tributaries are seriously, and perhaps irreversibly, polluted. Also, the reservoir created by the Three Gorges Dam was also seriously polluted (18).

Renewable Energy Alternatives

Restoration of rivers and streams by removing dams and culverts or (replacing them with bottomless arches) has been shown to increase fish populations by up to 25 percent (19). In particular, floodplain habitat restoration and side channels yielded the biggest gains for coho salmon. For steelhead salmon, constructed log jams and side channels were successful. Also, recently, Maine Department of Marine Resources Commissioner Pat Keliher announced that 50,000 alewives have been stocked this spring above the Penobscot River dams. The fish will swim downriver to the ocean later this summer; and when they return in four or five years, they will be able to return to spawning grounds because the restoration project will be complete. Besides restoring salmon habitat, the project will lead to huge increases in the population of other sea-run fish, including shad and alewives and boost fisheries in the Gulf of Maine, he said (20).

Replacing hydropower with low cost substitutes is a challenge. However, as suggested earlier, the cost of renewable energy alternatives, such as wind and solar power, continues to decline. Also, the addition of ethanol to gasoline to reduce the carbon footprint has been somewhat successful. However, the availability of cellulosic biofuel is problematic because a small number of producers. Furthermore, the state of the technology for turning biological materials like wood chips or nonfood plants straight into hydrocarbons was advancing but not yet ready for commercial introduction (21). Also, breaking down cellulose is expensive and arguably not environmentally sustainable because farmers turn vast amounts of land

into single-crop production, risking environmental damage from pesticides and fertilizers.

Recently, research has provided a potential breakthrough by converting cellulose into butanol, a compound with four carbon atoms providing more energy than two atom ethanol. Much of the research taking place at Tulane and Mississippi State Universities focuses on how animals such as zebras and pandas break down cellulose (22).

IBM has arguably taken a leadership role in using technology to create a more sustainable urban environment in their "Smarter Cities" initiative (23). In particular, as centers of business, culture and life, cities are logical places to integrate many of the Smarter Planet principles and innovations in public safety, transportation, water, building, social services and agencies. A new kind of solution, the IBM Intelligent Operations Center for Smarter Cities, synchronizes and analyzes efforts among sectors and agencies as they happen, giving decision makers consolidated information that helps them anticipate—rather than just react to—problems. By using these tested approaches, cities can manage growth and development in a sustainable way that minimizes disruptions and helps increase prosperity for everyone. Included in this comprehensive program are greater efficiencies in government, public safety, healthcare, energy, and traffic. Also, Totty (24) provides a wide range of activities for a more sustainable city. He suggests that urban populations around the world are expected to soar in the next 20 years, to five billion from more than three billion today. If the current rate of urbanization holds steady, cities will account for nearly three-quarters of the world's energy demand by 2030. Most of the increase will come in rapidly developing countries like China and India; China's cities alone will have to deliver water, housing, transportation and other services to 400 million additional urban dwellers by 2030 (25). Some of the recommendations include the use of micro wind turbines, pumped hydro storage and micro hydropower, pneumatic garbage collection, and green rooftops.

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